Scenario Simulation of Land Use/Cover Changes Based on Markov Model and Land Change Modeler in the Tokyo Metropolitan Area: Towards Future Sustainable Development

January 2020

Ruci WANG

Scenario Simulation of Land Use/Cover Changes Based on Markov Model and Land Change Modeler in the Tokyo Metropolitan Area: Towards Future Sustainable Development

A Dissertation Submitted to
the Graduate School of Life and Environmental Sciences,
the University of Tsukuba
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy in Science
(Doctoral Program in Geoenvironmental Sciences)

Ruci WANG

Abstract

Land Use/Cover (LULC) changes have lately been the great interest of governments and city planners due to the limited LULC resources, high recovery cost, and people's production and living conditions. LULC changes reflect the status of urbanization, industrialization, economic development, and social progress. However, urbanization and industrialization have placed a lot of pressure on natural resources, environmental protection, and sustainable development. To overcome this problem, ecological protection organizations and local governments have proposed several policies to control the LULC process for sustainable development. Meanwhile, it is crucial to simulate future LULC distribution under the various planning policies in the context of the current reality. Japan is a developed country that first implemented effective urban planning in Asia. In the initial stage of development, Japan learned from successful urban planning examples in Western countries. Subsequently, Japan created its own urban planning structure, taking into account its characteristics and urban development. The Tokyo Metropolitan Area (TMA) was replanned seven times from 1958 to 2017. The development pattern, urban functions, spatial distribution, and demand for residential space were considered

in the urban planning process during the different development stages. The urban development coefficient indicated that Japan entered the maturational period after 1999. The urban development pattern switched from urban expansion to urban improvement being guided by urban planning. The LULC trend over the past several years during the stable period is useful for the realization of LULC trends in the near future. Nowadays, the TMA is considered as an outstanding example of a megacity. Hence, monitoring the LULC change during the past several years in the TMA can provide the experience for other cities on urban planning. And simulating future LULC scenarios in the TMA also can give alternative direction for sustainable development. However, Japan's aging population and low birth rate have made it challenging to establish a strategy for sustainable development while maintaining a healthy living environment and urban vitality. Additionally, the decrease in population is a significant factor that affects at least the 2030 and 2050 future population structures and LULC composition.

The primary objective of this study is to employ remote sensing data and geographical information systems (GIS) techniques to analyze the spatiotemporal pattern of LULC change in the TMA from 2001 to 2017 and simulate the LULC change in 2030 and 2050 by considering the allocation of urban functions, sustainable development, and food demand.

Scenario simulation is an indispensable method of foreseeing future LULC

composition under various circumstances. Usually, the spontaneous scenario is simulated as a baseline to test the futurism of the current LULC. In this study, the spontaneous scenario was set as the basic scenario to gauge the model efficiency and distinctiveness of the other scenarios. Green spaces have several functions like preventing and remedying pollution, protecting natural resources, improving the living environment, and increasing economic efficiency. Green spaces with extensive foliage cover purify air and can keep water from draining. The afforestation of cities can mitigate urban climate change. Usually, the land surface temperature of green spaces can be 3 – 4 ℃ lower than agricultural areas and 10 ℃ lower than constructive land. Additionally, forests can reduce noise pollution, protecting people's health. By considering green spaces as a crucial LULC type that protects the living environment, the ecological security pattern construction scenario was developed.

Agricultural land plays an essential role in urban sustainability to ensure national food security and maintain a high level of self-sufficiency. However, urban development always has progressed by expanding into agricultural land for more space to obtain economic opportunities. Therefore, analyzing and simulating the future development of agricultural land can provide an improvement scheme to maintain the balance between urban construction and sustainable development. During urban development and economic growth, the relationship between agriculture protection and constructive

expansion has become increasingly precarious. More importantly, agricultural land is insurance against population increase and maintains healthy urban development. Hence, future LULC development in developed areas remains an ongoing challenge for promoting balanced urban improvement and supporting social development.

Ecological security means the green space should be protected at a maximum, which essential for sustainable urban development. The result of the ecological security pattern construction scenario is different from the spontaneous scenario and the food system localization scenario. The distinction among the three scenarios will increase from 2030 to 2050. The ecological security pattern construction scenario provides a pleasant living and natural environment, and supports sustainable development in the TMA. The simulated results of the spontaneous and food system localization scenarios in 2030 and 2050 show that the food system localization scenario differs greatly from the spontaneous scenario. The agricultural distribution under the food system localization scenario is abundant compared to the spontaneous scenario. These results were obtained by modelling variables settings.

In this study, I analyzed LULC change from 2001 to 2017 and simulated future LULC composition in 2030 and 2050 in the TMA. Natural resource protection, living environment improvement, food security provision, and sustainable development were considered the primary forces during the simulation. The resulting scenarios provided

three alternative distributions of LULC to accommodate population structure, urban development, and government policy. Scenario simulation is a crucial method of foreseeing future LULC distribution using accurate and realistic simulation outcomes. This study is significant as it uses the current LULC change to discuss future sustainability in the TMA.

Keywords: GIS; Land Use/Cover Changes; Remote Sensing; Scenario Simulation; Sustainable Development; Tokyo Metropolitan Area